CHAPTER 6

POWER CABLES

6-1. Components.

Power cables are generally made up of three components: conductor, insulation and protective covering. The single most important component of a cable is its insulation. The best way to ensure continued reliability of a power cable is through visual inspection and electrical testing of its insulation. The guidance provided here applies only to cables rated 600V AC or less and, to the occasional applications found in DC motor drives operating at 500, 600, or 700v DC or less.

6-2. Visual inspection.

A visual inspection of a power cable can be made with power on. However, if the visual inspection is to include touching, handling or moving cables in manholes or at terminations, then all circuits in the group to be inspected should be de-energized before the work is started.

a. Manhole installations. Manholes are not usually located inside buildings. Terminations and splices of non-lead cables should be squeezed in search of soft spots, and inspected for tracking or signs of corona. The ground braid should be inspected for corrosion and tight connections. Inspect the bottom surface of the cable for wear or scraping due to movement at the point of entrance into the manhole and also where it rests on the cable supports. Inspect the manhole for spalling concrete or deterioration above ground. If the manhole is equipped with drains, these may require cleaning or, in some instances, it may be necessary to pump water from the manhole prior to entrance. Do not enter a manhole unless a test for dangerous gas has been made and adequate ventilation gives positive assurance that entry is safe. High voltage cables may be present fireproofed with asbestos containing materials which pose additional health hazards. Potheads should be inspected for oil or compound leaks and cracked or shipped porcelains. The procelain surfaces should be cleaned and if the connections are exposed, their tightness should be checked. Since inspection intervals are normally one year or more, comprehensive records are an important part of the maintenance inspection. They should be arranged so as to facilitate comparison from one year to the next. Cables in manholes, ducts or below grade installations should be inspected for the following:

(1) Sharp bends in the cables.

(2) Physical damage.

(3) Excessive tension.

(4) Cables laying under water.

(5) Cable movement or dangling.

(6) Insulation swelling.

(7) Soft spots.

(8) Cracked protective coverings.

(9) Damaged fireproofing.

(10) Poor ground connections or high impedance to ground.

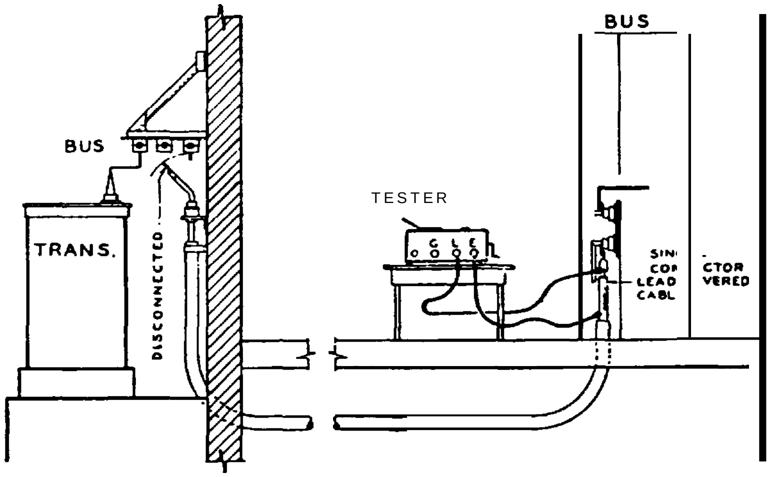
(11) Deterioration of metallic sheath bond.

(12) Corrosion of cable supports or trays.

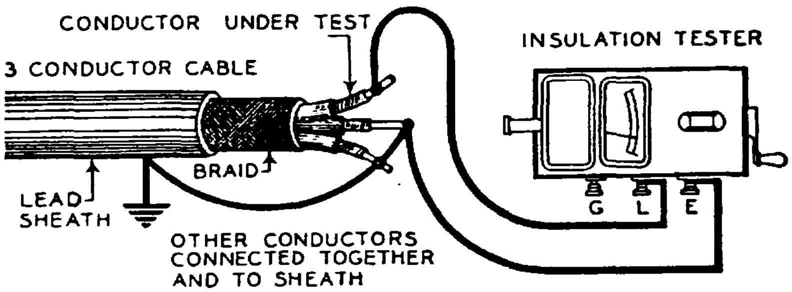
b. Raceway and cable tray installations. Since the raceway or cable tray is the primary mechanical support for the cable, it should be inspected for signs of deterioration or mechanical damage. The cable jacket should also be checked for abrasions or mechanical damage.

6-3. Cable insulation testing.

The electrical test most often conducted to determine the quality of low voltage cable insulation is the insulation resistance test (para 14-2). It is performed as a routine maintenance test for cables already in service or as an acceptance test for new cables. DC overpotential testing is another way of testing cable insulation. This test is performed primarily on medium and high voltage cables to test their dielectric strength and is not recommended for routine maintenance testing of low voltage cables. The insulation resistance test for low voltage cables is usually performed using a megohmmeter (para 13-4). It is a simple, quick, convenient and nondestructive test that can indicate the contamination of insulation by moisture, dirt or carbonization. Before testing any cable, the circuit must be de-energized. Once that is done, it is usually best to disconnect the cable at both ends in order to test only the cable, and to avoid error due to leakage across or through switchboards or panelboards. For an acceptance test, cable less than or equal to 300 V maybe tested at 500 V and cable greater than 300 V but less than 600 V maybe tested at 1,000 V. For a routine maintenance test, test voltage should be restricted to 60 percent of the factory test voltage. The test voltage should be applied from phase to ground on each conductor with the shielding tapes and metallic jackets also connected to ground (fig 6-l). While no general standard exists for minimum acceptable insulation resistance values for cables in service, a “rule-of-thumb” of one megohm of resistance (mini-



a.



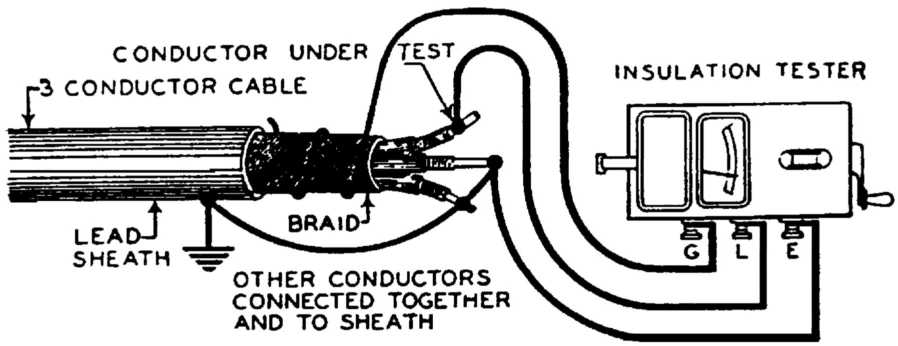
b.

Figure 6-1. Connections for Testing Low Voltage Cable Insulation: a) Test on single-conductor cable, b) Tests on multi-conductor cable.

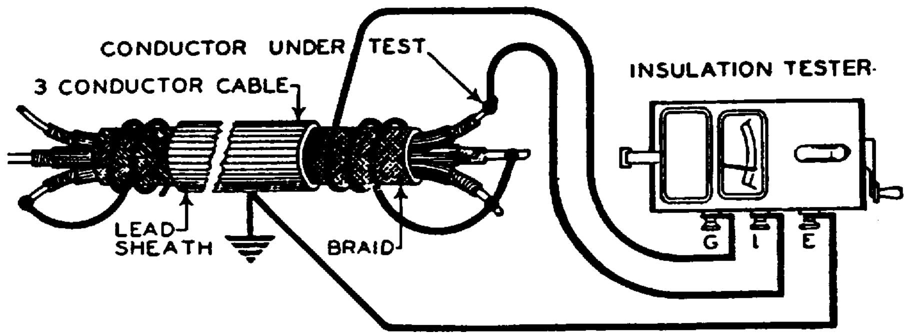
mum) per 1,000 V of applied test voltage is accepted. If a cable should fail the test, then further cable testing is required to pinpoint the failure location. A cable locator/fault finder can trace the exact path of buried or above ground cable and locate a fault. The insulation resistance test should be performed at regular periods and a record kept of the readings. Insulation resistance decreases with an increase in temperature. Thus, in order to properly interpret the results and to permit a reliable comparison of periodic readings, the readings should be corrected to a base temperature. Correction factors and methods are shown in the reference material of the megohmmeter manufacturer. It should be noted that persistent downward trends in insulation resistance indicate insulation deterioration even though the readings may be higher than minimum acceptable values.

6-4. Overpotential testing.

Both direct current (DC) and alternating current (AC) overpotential testing practices require the use of high voltages. Only properly trained, competent shop personnel should perform such tests. Because of the extra time, manpower and expense needed for overpotential testing, it is not recommended as a routine scheduled maintenance tool. The test is done mainly to seek out weaknesses in the cable



c.



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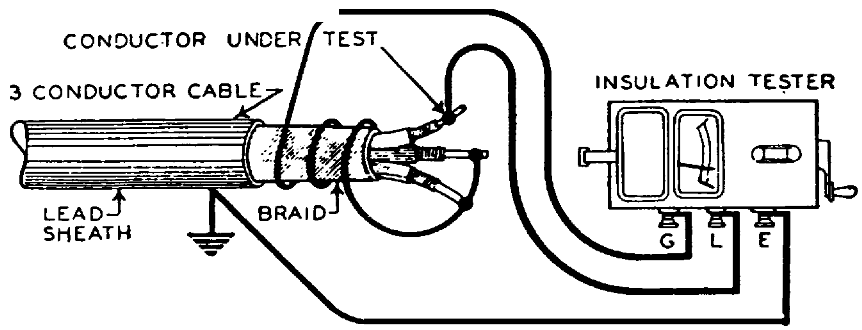
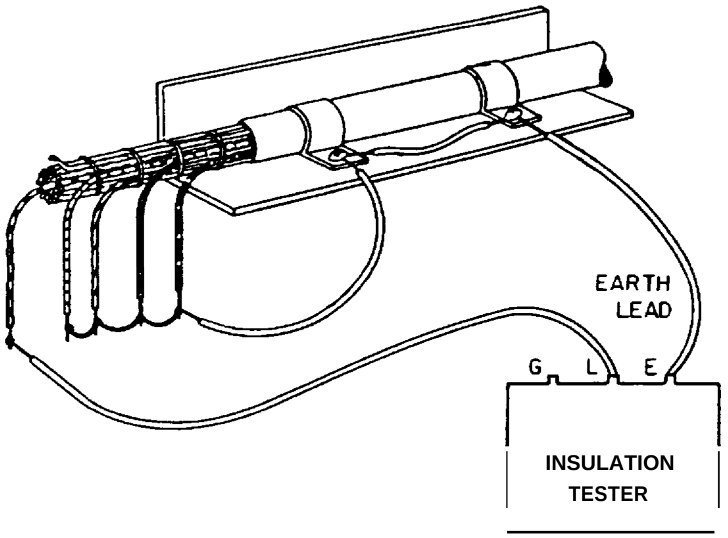
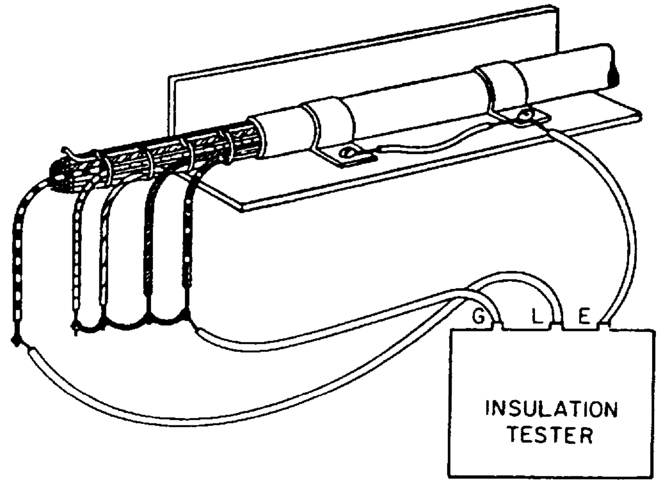


e.

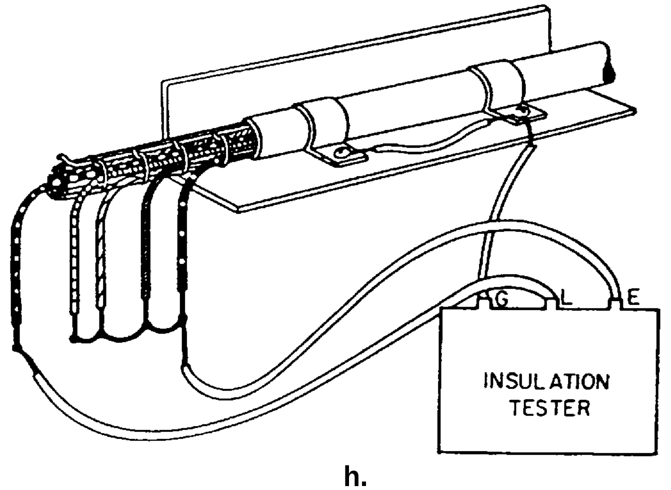
Figure 6-1. (Continued) c) Use of the "guard" terminal to eliminate measure of surface leakage across exposed insulation at one end of cable, d) Use of a "spare" conductor to guard both ends of a multi-conductor cable, e) Use of "guard" to eliminate all surface leakages except conductor under test.



f.



g.



h.

Figure 6-1. (Continued) f) Connection for testing total resistance between one conductor and all others plus ground, g) Testing one conductor leakage to ground only, h) Testing one conductor to others in the bundle-leakage to ground eliminated by guard.

insulation system that otherwise may not show up during insulation resistance testing. Overpotential testing may be desirable as an overall quality acceptance test after installation, modifications, or expansion of a feeder cable system; as an additional check of critical, emergency power feeder cables; as an additional quality check that is known to have conducted high current due to a short circuit fault in the connected equipment; or, as a quality check after cable splices have been made. Overpotential testing is not recommended as a periodic, routine maintenance test under three conditions. First, if the cable cannot be completely disconnected or isolated from the connected load(s) or auxiliary devices such as surge capacitors, lightning arresters, fuses, cutouts, and switchgear bus, second, if unacceptable readings have already been obtained from general insulation resistance testing, and third, if the cables are known to be laying under water.

a. Direct current (DC) tests. There are two methods used for DC overpotential testing. In the first method, the voltage is raised gradually to the specified level. The rate of increase should be adjusted to maintain a steady charging and leakage current. The current for a DC testis measured in microampere. Sixty to ninety seconds has been found to be an acceptable average time to reach the final test voltage level. When this level has been reached, leakage current readings are taken and recorded at O, 1, 2, 3, 4, and 5 minutes. After the last reading, the voltage is slowly lowered and the cable is allowed to fully discharge. The second method is called the step method. Using this procedure, the test voltage is raised in steps at given intervals. The leakage current is measured and recorded at each new voltage level as well as the O, 1, 2, 3, 4 and 5 minute intervals after the final test voltage has been reached. The step method is intended to catch an undesirable trend in the leakage current before the cable actually fails. The test can be stopped before the final voltage is reached. An engineering judgment will be required to determine if the cable should be left in service or if remedial measures should be taken. In both test methods, good interpretation of the leakage current magnitudes and the trends is necessary. Temperature, humidity, and insulation surface conditions affect the readings. Table 6-1 should be used as a guide in determining the specified test voltages.

b. Alternating current (AC) tests. AC overpotential testing is severe and possibly destructive to the cable under test. In the AC test, the voltage is quickly raised from zero to the specified level. The test is usually held for one minute. The current is measured in milliamperes; however, its value is not important. The reading of current is provided so that the person running the test can determine if the particular test set has sufficient capacity for the task at hand. If the cable withstands the one minute application, the test has been passed. Failure results in short circuit and a ruined portion of the cable. The test set is designed to trip off immediately upon detection of the fault current. Table 6-1 gives the recommended test levels.

6-5. Cable trouble-shooting.

Table 6-2 provides information regarding the most common cable failure: overheating. Probable causes of overheating cables are listed along with recommended practices to remedy the problems.

Table 6-1. Conductor sizes, insulation thickness, test voltages.

Rated Circuit Voltage, Phase to Phase, Volts	Conductor Size AWG or MCM*	INSULATION THICKNESS				A-C TEST VOLTAGE		D-C TEST VOLTAGE	
		100 Percent Insulatation Level		133 Percent Insulation Level		100 Percent Insulation Level	233 Percent Insulation Level	100 Percent Insulation Level	233 Percent Insulation Level
		mils	mm	mils	mm	kV	kV	kV	kV
0-600	14-9	30	0.76	30	0.76	4.0	4.0	12.0	12.0
	8-2	45	1.14	45	1.14	5.5	5.5	16.5	16.5
	1-4/0	55	1.40	55	1.40	7.0	7.0	21.0	21.0
	225-500	65	1.65	65	1.65	8.0	8.0	24.0	24.0
	500-1000	80	2.03	80	2.03	10.0	10.0	30.0	30.0

* MCM-Thousands of circular mils.

100 percent level - Cables in this category may be applied where the system is provided with relay protection such that ground faults will be cleared as rapidly as possible, but in any cause within 1 minute. While these cables are applicable to the great majority of cable installations which are on grounded systems, they may be used also on other systems for which the application of cables is acceptable provided the above clearing requirements are met in completely de-energizing the faulted section.

CABLE RATED O-600V
OZONE-RESISTANT EHYLENE-PROPYLENE RUBBER
INSULATION

133 Percent Level - This insulation level corresponds to that formerly designated for ungrounded systems. Cables in this category may be applied in situations where the clearing time requirements of the 100 percent level category cannot be met, and yet there is adequate assurance that the faulted section will be de-energized in a time not exceeding 1 hour. Also they may be used when additional insulation strength over the 100 percent level category is desirable.

(IPCEA S-68-51G, NEMA WC 8-1971).

Table 6-2. Cable maintenance--overheating problems.

Installation	Cause of overheating	Remedy
Cables in racks	Heat from lower cables in vertical racks rises and heats upper cables.	Provide baffles to deflect rising warm air.
	Cables spaced horizontally affected by mutual heating.	Increase space between cables. (For beat cooling, minimun center-to-center distance between cables should be twice the cable diameter).
	Cables closely spaced or in a location where heat is confined, such as near ceilings, etc.	If constricted portion of cable run is short, fans can be set up to provide cooling.
	External sources of heat.	Re-route cable or remove heat source.
		Shield cables from heat or ventilator with fan.
Cables in floor channels.	Mutual heating of cables that have been piled aimlessly in overcrowded floor channels.	Rack cables systematically and maintain spacing necessary to minimize mutual heating.
	Restriction of air circulation by solid covers on channels.	Where practical, replace solid covers with perforated covers to increase air circulation.
Cables in tunnels	Overloading	Re-route part of load from overloaded cables to cables carrying lighter loads.
	Mutual heating of cables spaced too closely on rack.	Space cables on racks to minimize mutual heating. Place cables near the floor.
		Force air circulation through tunnel.
	External sources of heat.	Insulate adequately from the external heat source.

Table 6-2. Cable maintenance--overheating problems--continued.

Installation	Cause of overheating	Remedy
Cables in underground ducts	Overloading, addition of loaded cables to duct bank without reducing the rating of cables already in bank	Transfer load from overloaded cables to cables carrying lighter loads. Place power cables in outside ducts with most heavily loaded cables at the corners of bank. Install ventilating covers on congested manholes. (A fan to force air out through a ventilating cover may help).
Cables buried in earth.	Overloading	Wetting dry soil improves its conductivity, and may slightly improve cable capacity. Only real remedy is transferring portion of load to another circuit.
Aerial Cables	Overloads. Cable in hot sun.	Reduce load. If practical, shade from sun. Capacity can be increased 15 percent by separating cables installed in one ring.
Cable Risers	Cable chosen for underground operation instead of in a conduit in air. Heating air rising and trapped at top of conduit. Exposure to sun.	Provide fans to cool risers during overload periods. Provide ventilating bushing at top of conduit. Shade risers, if possible.

Table 6-2. Cable maintenance--overheating problems--continued.

Installation	Cause of overheating	Remedy
All installations	High current because: low-power-factor equipment, and low voltage at receiving end.	Install capacitors to improve power factor. Raise voltage by means of taps on transformer or reduce voltage drop by moving single-conductor cables closer together. Move transformer closer to load. If load can be operated at two voltages, use higher value.
	Unbalanced currents because: unbalanced loading of phases, and unbalanced arrangement of single-conductor cables in group.	Balance arrangement of single-phase loads to divide current equally between three conductors. With two or more single-conductor cables in parallel per phase, consideration must be given to phase arrangement of cables to prevent unbalanced currents.